FINAL REPORT
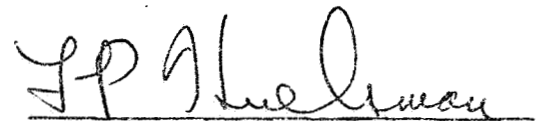

NASA RESEARCH GRANT NGL-03-002-136

ANALYSIS AND SYNTHESIS OF DISTRIBUTED-LUMPED-ACTIVE

NETWORKS BY DIGITAL COMPUTER

CASE FILE
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I. Introduction

This is the final report concerning research supported by the Instrumentation Division, Ames Research Center, National Aeronautics and Space Administration under grants covering the period 1 September 1967 to 31 August 1970, under step funding covering the period 1 September 1970 to 31 August 1972, and under a no-cost extension from 1 September 1972 to 31 August 1973. The research was concerned with the use of digital computational techniques in the analysis and synthesis of DLA (Distributed-Lumped-Active) networks. This class of networks consists of three distinct types of elements, namely, distributed elements (modeled by partial differential equations), lumped elements (modeled by algebraic relations and ordinary differential equations), and active elements (modeled by algebraic relations). Such a characterization is applicable to a broad class of circuits, especially including those usually referred to as linear integrated circuits, since the fabrication techniques for such circuits readily produce elements which may be modeled as distributed, as well as the more conventional lumped and active ones. The network functions which describe distributed elements, however, involve hyperbolic irrational functions of the complex frequency variable. The complexity of such functions make use of digital computational techniques most desirable in analyzing and synthesizing these networks. It was the purpose of the research performed under this grant to develop and apply a broad range of such techniques.

II. Detailed Research Goals

The major attention of the research performed under this grant
was concentrated on two goals. The first of these was the development
of viable large-scale digital computer software which had both analysis
and synthesis capabilities with respect to the DLA class of networks.
The second goal was the application of such software to a wide range
of DLA circuits, including both the optimization and improvement of
already-known configurations, and the investigation of new and original
ones in order to explore their potentialities. The results obtained
in the pursuit of these goals are treated in detail in the publications
listed in Sec. IV of this report. In this section, we will summarize
some of the major contributions documented in those items.

A first problem which is encountered in the study of DLA networks
is the difficulty of analyzing them. This problem is compounded be-
cause easily determined closed-form solutions for the parametric repre-
sentation of the distributed elements exist in only the simplest cases
of uniform, linear and exponential taper elements, and not for the gen-
eral case. One of the first projects undertaken in the course of the
research supported by this grant was the development of DLANET (Distributed-
Lumped-Active NETwork analysis program), a general purpose program for
sinusoidal steady-state analysis of DLA networks. DLANET includes options
for analyzing DLA circuits containing a wide range of distributed ele-
ments, as well as lumped and active ones. The distributed elements are
effectively and efficiently modeled for arbitrary specifications of
taper. It has proven to be a useful tool in many subsequent investigations

of such circuits. The justification of the modeling process used for the distributed elements in the program is given in (4).[1] A comparison of these modeling techniques with other numerical approaches for the determination of the parameters may be found in (13). An extension of the modeling technique to the case of distributed RC elements with multi-layers, and with two-dimensional variations of resistivity and contact patterns rather than the more usual one-dimensional ones is covered in (15). The theoretical basis for the overall DLANET program may be found in (2). The detailed extension of this theory to the actual program is covered in (6). An extension of the basic program to include the effects of differential-input active elements is given in (8). A description of a major revision of the program which greatly increases its capabilities is covered in (36).

One of the major difficulties encountered in designing viable synthesis methods for DLA networks is the difficulty of dealing with the transcendental irrational network functions describing such circuits. To overcome such difficulties, a general purpose digital computer optimization program GOSPEL (General Optimization Software Package for ELectrical networks) was developed. This program incorporates a wide range of optimization strategies and has proven to be a versatile and useful tool which has been applied with great success to a wide range of design problems in DLA network design, passive network synthesis, approximation theory, etc. In addition GOSPEL has been successfully applied to a broad spectrum of other disciplines, such as geological

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[1]Numbers in parentheses refer to the references given in Sec. IV.

studies, medical electronics, etc. Copies of the program have been wide-
ly requested by users both in the United States and abroad. The philo-
sophy of the program, together with listings and flow charts is thor-
oughly described in (5). A more general presentation is given in (18).
An additional optimization strategy which was added to the package is
discussed in (9).

One of the major techniques found to be of use in the application
of the optimization strategies implemented in the GOSPEL software
package is one known as complex optimization. This technique provides
direct synthesis of pole and zero locations using iterative methods.
It was developed under the grant, and was originally described in (7).
Additional details concerning its application are given in (16) and
(17). The use of the method in sensitivity determination is present-
ed in (23). A general subroutine for synthesizing DLA networks of
arbitrary configuration, using the complex optimization approach is
described in (14). An interactive program for applying complex
optimization to DLA networks specified only by means of their topology
is described in (42).

The optimization techniques developed in GOSPEL, are further
applied in DLANAP, (Distributed-Lumped-Active Network Analysis Programs),
a coordinated set of digital computer programs which provide a wide
range of tools for DLA network design. These include treatment of non-
dominant singularities, algorithms for construction of root-loci based
design charts, time-domain response analyses, sensitivity studies, etc.
The DLANAP programs are so structured that they may be used on moderate

sized computers. They have many options to permit the greatest possible freedom on the part of the user. The original concept of the use of digital computer algorithms for the construction of root-loci based design charts were given in (10). The DLANAP programs are covered in detail in (26).

The second goal of the research performed under this grant was the application of digital computer software to actual DLA circuits. A wide range of such investigations were made, and the results are covered in detail in the list of publications given in Sec. IV of this report. Among these results were the following:

1. A recomputation of the usually accepted values of the parameters of a lumped-distributed null network which showed those values to be in error (11).

2. Development of a DLA network configuration which has zero real-part sensitivity to changes in the gain of the active element independent of the Q of the dominant poles (19).

3. A general DLA network configuration which realizes a dominant bi-quadratic network function and only requires four network elements (21). An extensive set of design charts for this network has also been prepared (25).

4. A new DLA bandpass network configuration (24).

5. A new DLA high-pass network configuration (24).

6. Two new DLA low-pass network configurations (27) and (33).

7. A third-order active RC low-pass network configuration in which all the capacitors have the same value (29).

8. Development of a means for lowering the sensitivity of a well known DLA low-pass network (28) and (32).

9. A three-layer distributed RC network which produces two sets of transmission zeros (22).

10. The use of a three-layer distributed RC network to produce two pairs of complex conjugate zeros (34).

11. A DLA network which has a second-order dominant all-pass characteristic (35).

III. Acknowledgment

IV. List of Contract Publications

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